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Patentanmeldung Nr. Patent application No. Demande de brevet n°

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A light guiding device and a method for guiding light

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A light guiding device and a method for guiding light

The invention is related to a light guiding device having a coupling in surface for coupling in light radiation substantially in a first main direction perpendicular with respect to said coupling in surface, and having a coupling out surface for coupling out light radiation substantially in a second main direction perpendicular with respect to said coupling out surface, whereby the coupling out surface has other dimensions then the coupling in surface, whereby, for example, the light radiation is further guided in a light emitting element.

The light emitting element can be placed in front of said coupling out surface to direct the light radiation into it, but the light emitting element can also be glued with optical glue against the coupling out surface of the light guiding device, or even integral connected to it, for example, the light guiding device and the light emitting element can be molded in one injection molding operation. In that case the coupling out surface is only an area, and not an outer surface of material.

The main direction of the light radiation means that the light is radiated in different directions making relative small angles with said main direction, in particular smaller than about 45°, whereby the average direction of the light radiation is substantially the main direction.

Depending on the index of refraction of the material of the light guiding member, light radiation will be reflected back into the material of the light guiding member by the outer surfaces of that member, provided that the outer surface is smooth and that the angle of incidence is larger then a certain value, i.e. the angle of total reflection. The angle of incidence is the angle between the light beam and a line perpendicular to the surface to which the light beam is directed. Appropriate materials for guiding light are transparent thermoplastics, in particular polymethyl methacrylate (PMMA) or polycarbonate (PC). Such materials can be shaped for example by an injection molding process, by an extrusion process, or by a material removing laser operation.

A light guiding system comprising an element that emits light into a space to be illuminated is disclosed in US-A-2002/0167820. This publication describes a light guiding system for improving the lighting conditions of the passenger compartment of a motor

vehicle, whereby a plate-like light emitting element is arranged in the area of the interior lining of the vehicle roof. Light radiation is coupled in into the light emitting element through a lateral surface of the element, and light is emitted through the large front surface of said element into the passenger compartment of the vehicle in a homogeneous manner.

Light radiation can be coupled in into the light emitting element by means of a light generating unit, such as a fluorescent tube, extending along the oblong lateral coupling in surface of the light emitting element. As an alternative, a number of light sources, such as light emitting diodes (LED's) can be arranged in a row along said lateral coupling in surface. However, in all these cases, only a portion of the light radiated by the light generating unit will reach the lateral surface for coupling in the light radiation into the light emitting element. By making use of a reflector behind the light generating unit, the portion of the light radiation that reaches said lateral surface can be increased, but still there is much more light generated near said lateral surface than can be coupled in into the light emitting element.

Furthermore it is often desired that the directions of the light beams that leaves the light guiding device - and may be coupled in into the light emitting element - have relative small angles with said second main direction of the light radiation, being the direction perpendicular with respect to the coupling out surface of the light guiding device. Smaller angles of the light beams with the second main direction, i.e. a reduced angular distribution of the light radiation in the second main direction, will improve the guidance of the light in the light emitting element.

The object of the invention is to provide a light guiding device, whereby light radiation is guided from a relative small light source and is distributed over a larger area, in particular an oblong coupling out surface, whereby preferably the angles between the light beams and the main direction of the light radiation is decreased.

In order to accomplish that objective, the light guiding device comprises a number of plate-like light guiding members, each having a substantial rectangular lateral coupling in surface and a substantial rectangular lateral coupling out surface, whereby a portion of the plate-like light guiding members are stacked together to create the coupling in surface formed by said lateral coupling in surfaces abutting each other at their long sides, and whereby the coupling out surface is created by said lateral coupling out surfaces abutting each other at their short sides. Substantial rectangular means that the shape may be rectangular, but the shape may also be bordered by two long sides and two short sides, which sides are more or less curved in a two dimensional plane or in a three dimensional space.

By making use of a number of plate-like light guiding members, the light radiation can be distributed over a long coupling out surface, while the coupling in surface has an appropriate shape to be placed in front of a light source, for example a square shape.

In one preferred embodiment, the coupling in surface has a substantial rectangular shape whereby the long side is less then five times longer than the short side, and whereby the coupling out surface has an oblong shape having a length of more than five times, preferably more than ten times, the length of said long side of the coupling in surface. Preferably, the coupling in surface has a substantial square shape.

In one preferred embodiment, each of the plate-like light guiding members is provided with a lateral reflecting outer surface for reflecting the light radiation, which lateral reflecting outer surface is positioned at an angle to said first main direction and which reflecting outer surface directs the light radiation substantially in the second main direction towards the coupling out surface. Preferably, the angle between said reflecting outer surface and said first main direction is between 15° and 55°, more preferably between 35° and 45°, and in one preferred embodiment about 40°. Thereby, the second main direction of the light radiation can be substantial perpendicular with respect to the first main direction.

The reflecting outer surfaces of the light guiding members may be flat surfaces, but the distribution of the light radiation, i.e. the distribution of the light intensity, in the coupling out surface of the light guiding device can be influenced by making use of curved reflecting outer surfaces. The presence of said reflecting outer surfaces in the light guiding members creates the possibility of a smaller dimension of the light guiding device in the direction of the light radiation leaving the light guiding member through the coupling out surface, i.e. in the second main direction.

In one preferred embodiment, the cross section area - perpendicular to said first main direction - of each plate-like light guiding member increases in the first main direction. Preferably, the increase of the cross section area starts at the lateral coupling in surface of each light guiding member.

The increasing cross section area, in particular created by diverging lateral surfaces bordering the lateral coupling in surface of each light guiding member, results in smaller angles between the light beams and the first main direction after the light radiation has passed the relevant portion of the light guiding member, because the diverging lateral outer surfaces reflects the light beams in a direction having such smaller angles relative to said first main direction. The result is a reduced angular distribution of the light radiation in the main direction. Said diverging lateral outer surfaces can be flat, but may also have a

parabolic or other shape, which shape may further improve the light directional effect on the light beams.

The conversion of the cross section of the light guiding device – perpendicular to the first and second main direction of the light radiation – is achieved by guiding the light radiation in the device through a number of separate plate-like light guiding members. Thereby, the light radiation is divided into portions, so that each portion can be guided through a light guiding member to the desired location. Furthermore, the cross section in each light guiding member increases because of the diverging lateral surfaces, so that the coupling out surface can have an oblong shape. These are important characteristics of the light guiding device. Less important are the way the light radiation is guided into said light guiding members and the way they leave the members.

The light radiation can enter the light guiding members through their lateral coupling in surfaces, which form together the coupling in surface of the light guiding device. Thereby, in one preferred embodiment, near the coupling in-surface portions of the plate-like light guiding members make optical contact, and preferably be glued together with optical glue having about the same refractive index as the material of the light guiding members itself. So, there are no barriers for the light radiation in the material of the light guiding device near said coupling in surface, but further away from said coupling in surface portions of the light radiation are caught (coupled in) in each of the stacked together light guiding members. The aim of the optical contact, for example the use of optical glue, is to mix the light radiation properly and to create a homogenous light distribution in the whole stack of light guiding members after the coupling in surface, so that equal parts of the light radiation enter each of the stacked together light guiding members. Instead of, or additional to, the application of glue, a massive additional light guiding member can be placed in front of the coupling in surface of the light guiding device, or can be glued against the coupling in surface. The length of such additional light guiding member, or the length of the glued together portions of light guiding members can be between 20 mm and 100 mm, preferably between 35 mm and 70 mm, more preferably about 50 mm.

Near the coupling out surface of the device, the lateral surfaces of the light guiding members can be glued together, so that there are no barriers for the light radiation in the material of the device near its coupling out surface. It is also possible to place an additional massive light guiding member in front of the coupling out surface of the light guiding device, or to glue such additional member against the coupling out surface.

In one preferred embodiment, the thickness of the plate-like light guiding members near the coupling out surface increases in the second main direction, so that the short side of the coupling out surface is longer than the thickness of the plate-like light guiding member further away from the coupling out surface. Thereby the substantial parallel outer surfaces of the plate-like members diverge in said second main direction near said coupling out surface. An effect of the diverging outer surfaces is a further decrease of the deviation of the directions of the light beams from the second main direction, i.e. a reduced angular distribution of the light radiation.

Preferably, portions of the plate-like light guiding members near said coupling in surface extend in different substantial parallel planes, while the portions of the plate-like light guiding members near said coupling out surface extend in substantial one plane. Thereby the planes may be flat or curved in order to adapt the shape of the light guiding device to the shape of the available space to accommodate the device.

The invention is furthermore related to a method for guiding light through a light guiding device whereby light radiation is coupled in substantially in a first main direction perpendicular with respect to the coupling in surface, and whereby light radiation is coupled out substantially in a second main direction perpendicular with respect to the coupling out surface, whereby the coupling out surface has other dimensions then the coupling in surface, and whereby the light radiation is guided by a number of plate-like light guiding members, each having a substantial rectangular lateral coupling in surface and a substantial rectangular lateral coupling out surface, whereby a portion of the plate-like light guiding members are stacked together to create the coupling in surface formed by said lateral coupling in surfaces abutting each other at their long sides, and whereby the coupling out surface is created by said lateral coupling out surfaces abutting each other at their short sides.

The invention will now be further elucidated by means of a description of two embodiments of a light guiding device, whereby reference is made to the drawing comprising figures which are only schematic representations, in which:

Fig. 1 is a top view of a light guiding member;

Fig. 2 and 3 are side views of the light guiding member shown in figure 1;

Fig. 4, 5 and 7 are views of a first embodiment of a light guiding device;

Fig. 8 is a view of the light guiding device shown in figures 4-7; and

Fig. 9 is a perspective view of the light guiding device shown in figures 4-8.

Fig. 10, 11, 12 and 13 are views of a second embodiment of a light guiding device; and

Fig. 14 is a perspective view of the second embodiment.

According to the first embodiment, the light guiding device is composed of five substantial plate-like light guiding members, and figures 1, 2 and 3 show such a light guiding member. In this example, the material of the light guiding member is polycarbonate, which is a transparent thermoplastic material that can be shaped by means of an injection molding operation. The outer surfaces of the member are smooth, so that light that is coupled in will be reflected by said outer surfaces, provided that the angle of incidence with respect to the relevant outer surface is larger then the angle of total reflection (i.e. the critical angle of total reflection). The angle of total reflection depends on the value of the index of refraction of the material of the light guiding member and the value of the index of refraction of the medium bordering the relevant outer surface of the light guiding member.

The index of refraction of polycarbonate is about 1.6 and the index of refraction of air is about 1.0, thereby the angle of total refraction is about 39°. That means that all light beams having, with respect to the relevant outer surface of the light guiding member, an angle of incidence larger than 39° will be totally reflected back into the material of the light guiding member. Only in case of a light beam having an angle of incidence smaller than 39°, the light of the beam will not be reflected, but will be coupled out.

The light guiding member comprises a first part 1, a second part 2, and a third part 3. The light radiation guided by the member is coupled in through the lateral coupling in surface 4. Therefore a lamp can be placed in front of lateral coupling in surface 4. Lateral coupling in surface 4 borders two lateral outer surfaces 5,6, which lateral outer surfaces 5,6 diverge in the first main direction (arrow 7) of the coupled in light radiation. The light coupled in through lateral outer surface 4 radiates in different directions making relative small angles with said first main direction 7, in particular smaller than about 45°, whereby the average direction is substantially the first main direction 7.

In figure 1 three light beams are represented by striped lines 8,9,10, which light beams are coupled in through lateral coupling in surface 4. Light beam 8 is reflected by lateral outer surface 5, and light beam 10 is reflected by lateral outer surface 6, and light beam 9 is directed at a smaller angle with respect to the main direction 7, so that light beam 9 does not reach the lateral outer surfaces 5,6. Thereby the divergence angle

radiation having a larger angle relative to the first main direction 7 is reflected by the lateral outer surfaces 5,6, whereby the angle relative to the first main direction 7 decreases after reflection, so that the diverging part 1 of the light guiding member provides for a reduction of the angular distribution of the light radiation around the first main direction 7.

The second part 2 of the light guiding member has a lateral reflecting outer surface 11 being positioned at an angle of about 45° with respect to the first main direction 7. Therefore, most of the coupled in light radiation coming from the first part 1 will be reflected towards the third part 3 of the light guiding member. The second main direction, i.e. the average direction of the light radiation reflected by reflecting outer surface 11, is indicated with arrow 12, and is directed at an angle of about 90° with respect to the first main direction 7.

The third part 3 of the light guiding member comprises a portion where the thickness of the plate-like material increases, seen in the second main direction 12. Light radiation reflecting against the diverging outer surfaces 14,15 of the third part 3 has a smaller angle with respect to the second main direction 12 after the reflection, so that the diverging surfaces 14,15 provides for a reduction of the angular distribution of the light radiation around the second main direction 12. The reduction of the angular distribution of the light radiation is similar to the reduction in the first part 1 of the light guiding member.

The light radiation guided by the light guiding member is coupled out through lateral coupling out surface 16 having a much larger surface area then the surface area of the lateral coupling in surface 4, and furthermore the angular distribution of the light radiation is reduced. Thereby the light guiding member provides for an appropriate distribution of the light intensity over the lateral coupling out surface 16. Depending on the requirements, the outer surfaces of the light guiding member, in particular the outer surfaces 5, 6 and 11, can be curved in stead of flat, in order to adapt the distribution of the light intensity to the requirements.

Lateral coupling out surface 16 can be placed against or near the lateral surface of a plate-like light emitting element, in order to couple in the light radiation from the light guiding member into the light emitting element. In another embodiment, the light emitting element, or another element in which the light has to be coupled in, can be connected to the third part 3 by means of optical glue or can be formed as one integrated part, for example produced in one injection molding operation.

Lateral coupling out surface 16 can be flat or can be provided with a certain profile in order to improve the distribution of the outgoing light radiation. For example,

lateral coupling out surface 16 can be provided with cylindrical lenses, whereby the axes of the cylinders are perpendicular to the plane of the plate-like light guiding member.

The dimensions of the light guiding member can be as follows. The thickness of the plate-like member can be between 1 mm and 5 mm, and is preferably about 3 mm. Said diverging outer surfaces 14,15 may diverge to a thickness of 0.5 mm to 3 mm more, preferably 1 mm to 2 mm more than the thickness of the second part 2 of the light guiding member.

Figures 4, 5, 6 and 7 are views of a first embodiment of a light guiding device comprising five stacked together light guiding members 21,22,23,24,25 of the kind as represented in the figures 1-3. The five light guiding members 21,22,23,24,25 extend in mutual parallel planes and are stacked together in such a way that the lateral coupling in surfaces of the five members 21,22,23,24,25 form together one flat and substantially square coupling in surface 26. The total lengths of each of the five light guiding members are different, so that the five lateral coupling-out-surfaces 27,28,29,30,31 can form together one elongated coupling out surface. Thereby, the part of each member 21,22,24,25 near the respective lateral coupling out surface 27,28,30,31 is bended out of the respective plane of the remainder of the relevant member 21,22,24,25, except for member 23, so that the lateral coupling out surfaces 27,28,30,31 are located in line with the lateral coupling out surface 29 of light guiding member 23 in the middle of the stack of light guiding members.

Figure 8 shows, in a larger scale than figures 4-7, a view of the light guiding device, from the side where the light radiation is coupled in, i.e. the side where coupling in surface 26 is located. Figure 9 is a perspective view of the light guiding device, whereby a lamp 32 is represented, which lamp 32 emits light radiation towards the coupling in surface 26 of the light guiding device.

The figures show that the substantially square coupling in surface 26 is build up out of the five lateral coupling in surfaces of each of the light guiding members 21,22,23,24,25. Thereby, the five stacked together light guiding members 21,22,23,24,25 may at least partly be glued together with optical glue, so that light radiation can pass adjacent surfaces of the stacked together members. In particular in the area near the coupling in surface 26, the members can be glued together, so that they form one body in optical sense. Thereby the distribution of the light radiation over the light guiding members 21,22,23,24,25 can be improved.

Figure 10-14 show a second embodiment of a light guiding device, whereby

is substantial parallel to the second main direction (arrow 42), i.e. the average direction of the coupled out light radiation. Figure 10 is a front view, perpendicular the planes of the three plate-like light guiding members 43,44,45. Figure 11 is a view of the device from the right side of figure 10. Figure 12 is a view of the device from the lower side of figure 10, showing the coupled in surface 46, and figure 13 is a view of the device from the upper side of figure 10, showing the three lateral coupling out surfaces 47,48,49 of the three plate-like light guiding members 43,44,45 respectively, which three lateral coupling out surfaces 47,47,49 together form the oblong coupling out surface of the device. Figure 14 is a perspective view of the second embodiment of a light guiding device.

The second embodiment has a coupling in surface 46 which is formed by the mutually abutting lateral coupling in surfaces of the three plate-like light guiding members 43,44,45. The coupling in surface 46 is substantial square, because the three rectangular lateral coupling in surfaces of the light guiding members 43,44,45 are abutting each other at their long sides. A lamp can be placed in front of the coupling in surface 46 to couple in light radiation substantial in the first main direction 41.

The portion of the device bordering the coupling in surface 46 has a rectangular cross section – perpendicular to the first main direction 41 – and the three light guiding members 43,44,45 are glued together with optical glue in that area, so that light radiation can pass the adjacent outer surfaces of the light guiding members 43,44,45. At some distance from the coupling in surface 46, where the three light guiding members do not completely overlap each other anymore (see figure 10), the three light guiding members are optically separated from each other, so that each of the three light guiding members guides about one third of the total coupled in light radiation towards the respective lateral coupling out surfaces 47,48,49.

Each of the three light guiding members 43,44,45 have diverging lateral outer surfaces 50,51, 52,53 and 54,55 respectively, resulting in a reduction of the angular distribution of the light radiation during the guidance of the light through the light guiding members 43,44,45, as explained before.

Near the coupling in surface 46 the three plate-like light guiding member 43,44,45 are positioned in three mutual parallel planes, but near the coupling out surface 47,48,49 all three light guiding members 43,44,45 are positioned in the same plane, being the plane of light guiding member 44 located in the middle. Therefore, light guiding member 43 has an inclined part 56 and light guiding member 45 has an inclined part 57, both parts 56,57 making an angle with respect to the parallel planes of the light guiding members 43,44,45.

The parts of the light guiding members 43,44,45 near the coupling out surface 47,48,49 are glued together at their lateral surfaces, which lateral surfaces are parallel with respect to each other in that area. The coupling out surface of the device is formed by the three rectangular lateral coupling out surfaces 47,48,49, which are abutting each other at their short sides, so that an oblong coupling out surface is obtained.

The outer surfaces of the light guiding device and/or the outer surfaces of the individual light guiding members, or portions of said surfaces, can be provided with a cladding, i.e. a coating having a low index of refraction, lower than the material of the light guiding member itself. Such cladding ensures the internal reflection of the outer surfaces, in particular when that surface is in contact with another object.

The embodiments of the light guiding member and the light guiding device as described above are only examples; a great many other embodiments are possible.

CLAIMS:

1. A light guiding device having a coupling in surface for coupling in light radiation substantially in a first main direction perpendicular with respect to said coupling in surface, and having a coupling out surface for coupling out light radiation substantially in a second main direction perpendicular with respect to said coupling out surface, whereby the coupling out surface has other dimensions then the coupling in surface, characterized in that the device comprises a number of plate-like light guiding members, each having a substantial rectangular lateral coupling in surface and a substantial rectangular lateral coupling out surface, whereby a portion of the plate-like light guiding members are stacked together to create the coupling in surface formed by said lateral coupling in surfaces abutting each other at their long sides, and whereby the coupling out surface is created by said lateral coupling out surfaces abutting each other at their short sides.

2. A light guiding device as claimed in claim 1, characterized in that the coupling in surface has a substantial rectangular shape whereby the long side is less then five times longer than the short side, and whereby the coupling out surface has an oblong shape having a length of more than five times, preferably more than ten times, the length of said long side.

3. A light guiding device as claimed in any one of the preceding claims, characterized in that each of the plate-like light guiding members is provided with a lateral reflecting outer surface for reflecting the light radiation, which lateral reflecting outer surface is positioned at an angle to said first main direction and which reflecting outer surface directs the light radiation substantially in the second main direction towards the coupling out surface.

4. A light guiding device as claimed claim 3, characterized in that the angle between said reflecting outer surface and said first main direction is between 15° and 55°, preferably between 35° and 45°, more preferably about 40°.

5. A light guiding device as claimed in any one of the preceding claims, characterized in that the cross section area - perpendicular to said first main direction - of each plate-like light guiding member increases in the first main direction.

6. A light guiding device as claimed in claim 5, characterized in that the increase of the cross section area starts at the lateral coupling in surface.

7. A light guiding device as claimed in any one of the preceding claims, characterized in that near the coupling in surface portions of the plate-like light guiding members make optical contact, and are preferably glued together with optical glue.

8. A light guiding device as claimed in any one of the preceding claims, characterized in that the thickness of the plate-like light guiding members near the coupling out surface increases in the second main direction.

9. A light guiding device as claimed in any one of the preceding claims, characterized in that the portions of the plate-like light guiding members near said coupling in surface extend in different substantial parallel planes, while the portions of the plate-like light guiding members near said coupling out surface extend in substantial the same plane.

10. A method for guiding light through a light guiding device whereby light radiation is coupled in substantially in a first main direction perpendicular with respect to the coupling in surface, and whereby light radiation is coupled out substantially in a second main direction perpendicular with respect to the coupling out surface, whereby the coupling out surface has other dimensions then the coupling in surface, characterized in that the light radiation is guided by a number of plate-like light guiding members, each having a substantial rectangular lateral coupling in surface and a substantial rectangular lateral coupling out surface, whereby a portion of the plate-like light guiding members are stacked together to create the coupling in surface formed by said lateral coupling in surfaces abutting each other at their long sides, and whereby the coupling out surface is created by said lateral coupling out surfaces abutting each other at their short sides.

ABSTRACT:

A light guiding device having a coupling in surface (46) for coupling in light radiation substantially in a first main direction (41) perpendicular with respect to said coupling in surface (26;46), and having a coupling out surface (47,48,49) for coupling out light radiation substantially in a second main direction (42) perpendicular with respect to said coupling out surface. The coupling out surface has other dimensions then the coupling in surface (46). The device comprises a number of plate-like light guiding members (43,44,45), each having a substantial rectangular lateral coupling in surface and a substantial rectangular lateral coupling out surface (47,48,49). A portion of the plate-like light guiding members are stacked together to create the coupling in surface (46) formed by said lateral coupling in surfaces abutting each other at their long sides. The coupling out surface (47,48,49) is created by said lateral coupling out surfaces abutting each other at their short sides.

Fig. 14

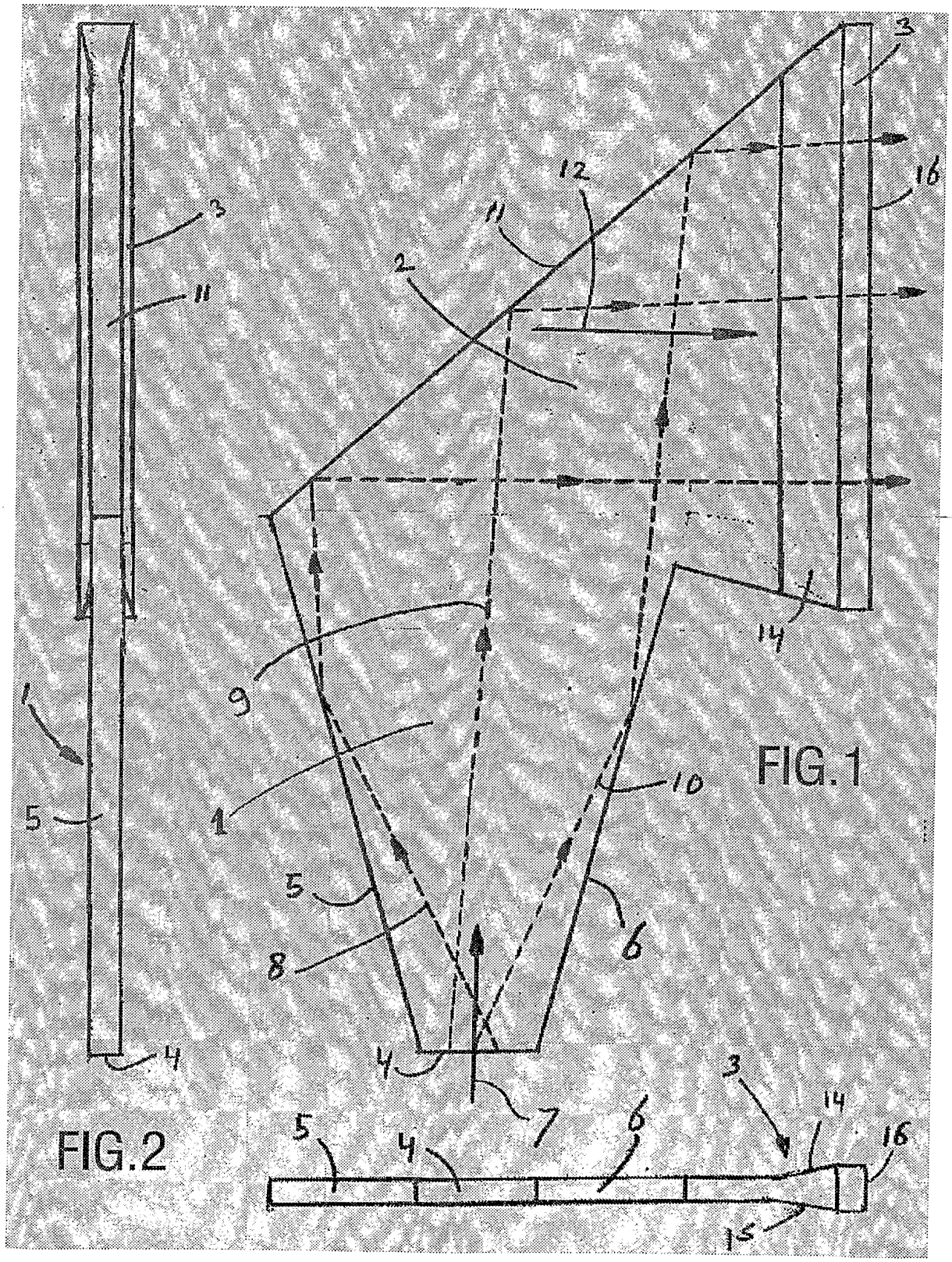
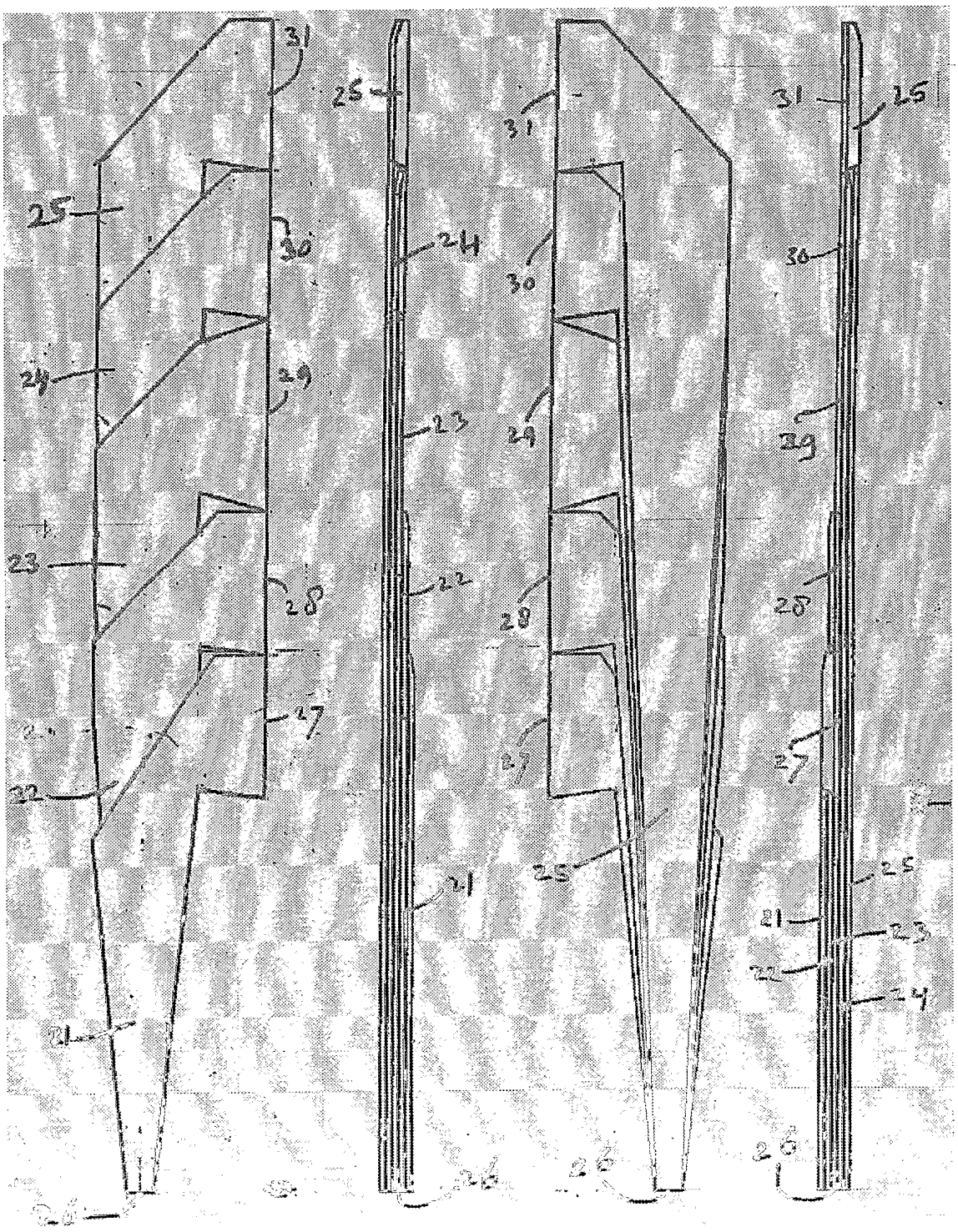


FIG.1

FIG.2

FIG.3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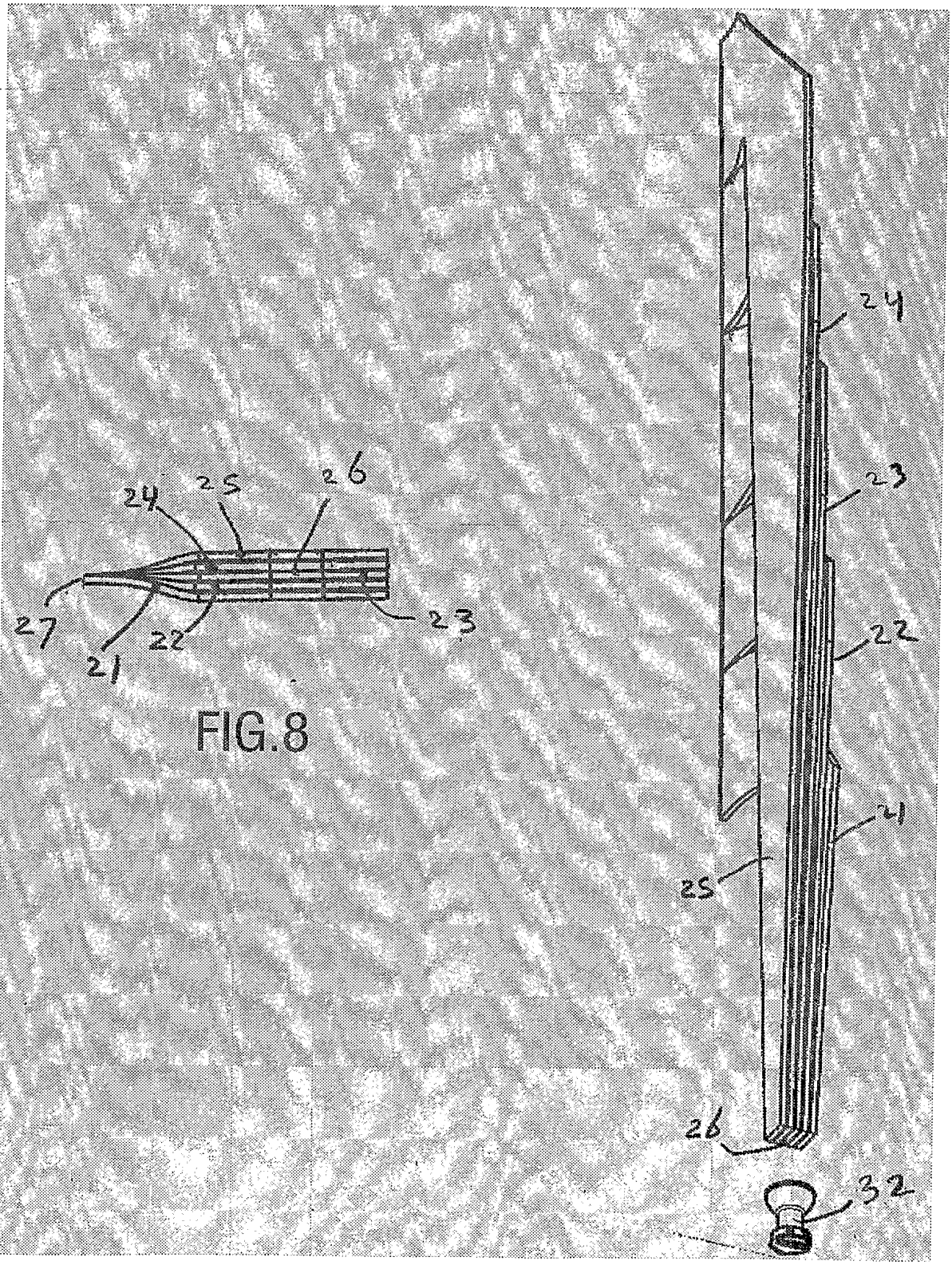

FIG.8

FIG.9

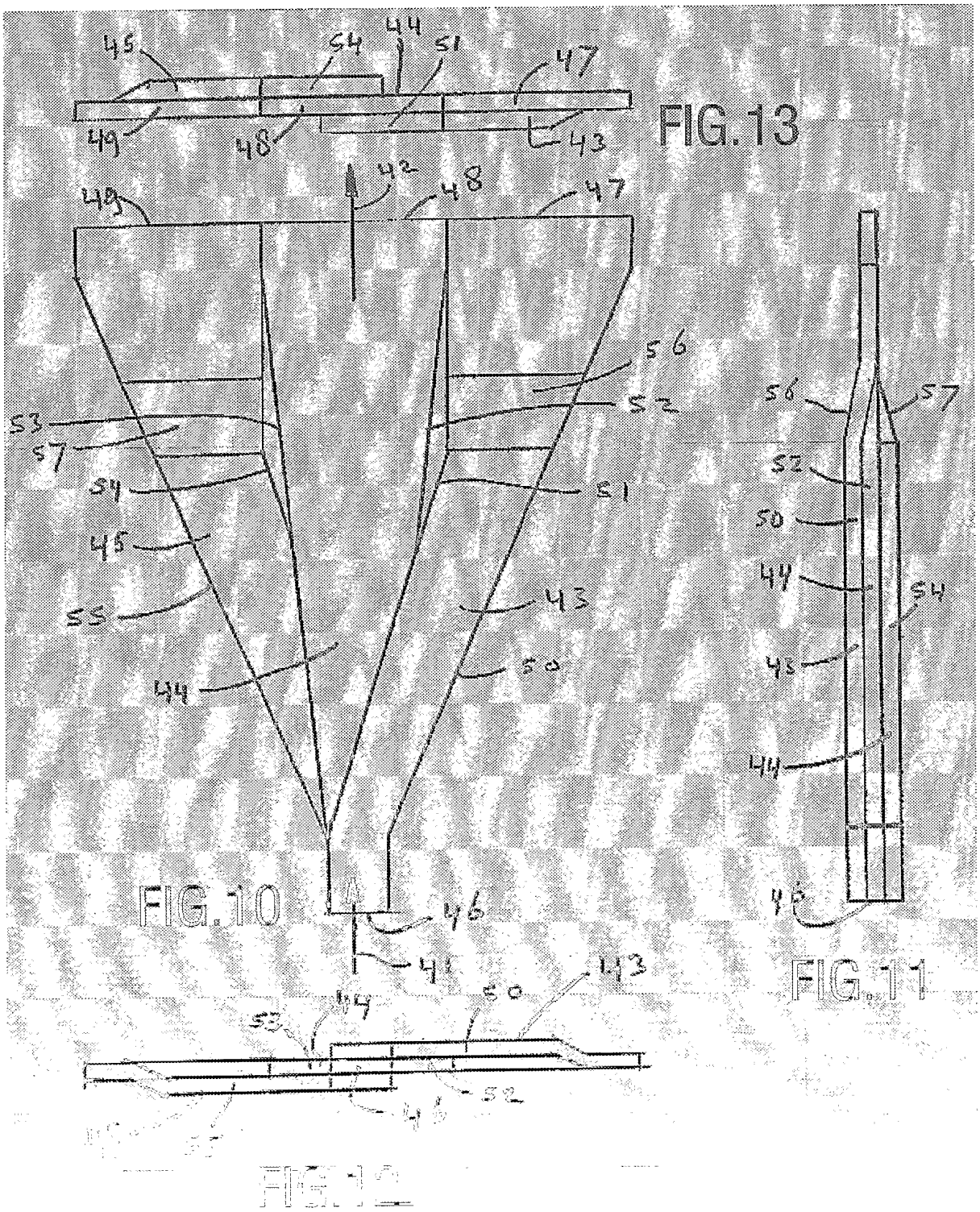

FIG. 13

FIG. 10

FIG. 11

FIG. 12

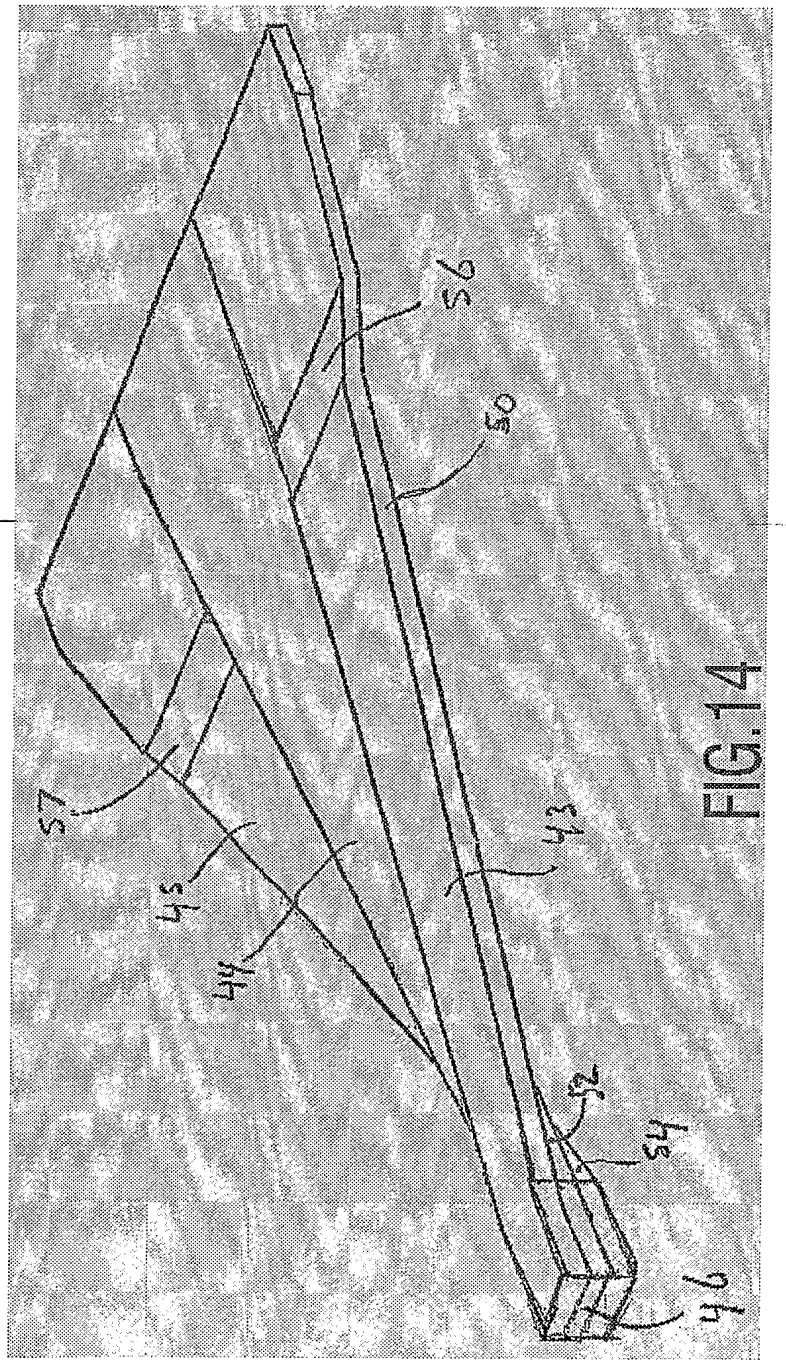

FIG.14